Building Research Establishment Digest

Cl/SfB 81 (M5)

DIGEST 153

May 1973

Motorway noise and dwellings

The L_{10} (18-hour) noise index has been adopted by Government to implement planning and remedial measures aimed at reducing the impact on people of road traffic noise. This digest reviews the current position on standards and suggests general design rules for estimating L_{10} at the planning stage, based on published research data confirmed to a limited extent by field tests on sites adjacent to motorways. It also gives guidance on the effects of roadside barriers and describes a simplified method of measuring L_{10}.

This digest supersedes No 135 which is now withdrawn.

The current position on standards

'One of the most disturbing features created by a new road is traffic noise. This is particularly so where new roads cut through areas of residential development. For the reduction of noise levels the Urban Motorways Committee (**New roads in towns** HMSO: 1972) place the main emphasis on road design. But the Committee recognise that it may not in all cases prove possible to achieve acceptable levels by such means. Where it does not prove possible to achieve the acceptable level through planning they recommend that there should be a right for the householder to claim and a duty to the highway authority to provide sound insulation. . . . The Government believe that this is the right approach.' (Extract from Government White Paper **Development and compensation—Putting people first** Cmnd 5124; HMSO: 1972)

L_{10} (18-hour) is the arithmetic average hourly value of the level of noise in dB(A) at one metre from the façade of a dwelling, exceeded for just 10 per cent of the time between the hours of 6 am and midnight on any normal weekday. L_{10} provides a meaningful correlation with social response and it can be estimated at the planning stage. Subsequent references in this digest to L_{10} are to values taken over an 18-hour day.

The following quotations are relevant to the choice of an acceptable level on the L_{10} index.

In recommending that existing residential development should in no circumstances be subjected, as an act of conscious public policy, to more than 70 dB(A) on the L_{10} index, the Noise Advisory Council stressed that 'this did not represent a standard of what is desirable and that planners wherever possible should design to lower levels'. (Hansard, 24 June 1971.) The Urban Motorways Committee in considering the Noise Advisory Council recommendation were 'unhappy with a limit which, on present evidence, only just avoids a majority of people being dissatisfied, and . . . would prefer to see a lower level'. In a Circular, 'Planning and Noise' (No 10/73, HMSO, 1973), the Department further stated 'There should be a strong presumption against permitting residential development in areas which are or are expected to become subject to excessive noise . . . the strong presumption should certainly apply where noise levels are in excess of 70 dB(A) on the L_{10} scale.'

When considering the level of noise for a particular planning situation and seeking to strike a balance between the desirable and the practicable levels the

absolute value of the noise level may not be the only factor to bear in mind. It may be worth while to consider also the level of increase in noise which the projected development would cause. The motorway could cause an increase in L_{10} from, say, 50 to 70 dB(A) and it is likely that the social impact of this change would be greater than an increase from 65 to 70 dB(A) say in another situation even though the final value is the same in both cases.

The Department of the Environment has also issued a design guide for architects **New housing and road traffic noise** (Design Bulletin 26, HMSO: 1972) which deals with ways in which the road traffic noise to which new housing is exposed may be reduced and examines the costs of various noise-reducing techniques.

Evaluating the noise exposure

Wind conditions Wind and weather conditions at any site may vary daily or even hourly. The wind direction in particular influences attenuation of noise with distance—sometimes leading to as much as 10 dB(A) difference between upwind and downwind conditions. As all sites will have adverse conditions at times, it is reasonable to base noise estimates on moderately adverse conditions. Accordingly, throughout this digest all predictions of L_{10} assume an adverse wind component, from the road to the dwelling, of about 10 km/h. It is suggested that this adverse wind condition should be the basis for design purposes, even though more favourable conditions will at times prevail. It follows too that on-the-spot measurements of motorway noise can only be used as a basis for the application of standards if they are made under the wind conditions here defined.

By measurement If the motorway already exists, the most direct procedure is to measure the noise exposure at the housing site, provided that no major changes, such as pulling down buildings which intervene, are proposed. Site measurements should be made at the appropriate positions and heights above ground, in wind conditions approximating to those defined above. If the measurements are made in open surroundings away from any wall or building, 3 dB(A) should be added to the readings to allow for the increase of sound pressure due to reflection at the face of the new buildings when they are erected. Measurements can be restricted to key points, if required, and the effect of distance on the measured noise level can be calculated for other points as explained later; in any case the effect of screening by other new dwellings will have to be estimated, and this is discussed later. The measured noise levels should be adjusted to take account of any foreseeable increase in traffic flow on the road. Any substantial change in areas of hard paving may call for a further adjustment (*see* Ground absorption).

Thus site measurements will nearly always require modification, if only to obtain standardised conditions. Methods of measuring L_{10} are described on pages 6 and 7.

By calculation If the motorway does not exist at the building design stage, noise levels must be estimated. The planned capacity and traffic movement should be applied to the basic chart for noise prediction, Fig 1, which shows the noise exposure to be expected 1 metre from the façade of a building 30 metres from the kerb line of the nearest traffic lane, for various traffic densities comprising 20 per cent heavy vehicles moving at a mean speed of 75 km/h on a level road under the stated wind conditions. To obtain a correction for other traffic speeds, reference can be made to Fig 2. For distances other than 30 metres a further correction has to be made, as indicated in Fig 3. For locations exposed to noise from more than one road, noise levels may be combined progressively, as set out in Fig. 4.

Traffic composition and road gradient

Gradients in roadways and the proportion of heavy vehicles in the traffic flow both influence the noise level. The predictions from Fig 1 are based on 20 per cent of heavy vehicles. If it is known that the proportion will be 40 per cent, the noise prediction should be increased by 2 dB(A); if on the other hand only 10 per cent of the vehicles are expected to be heavy, the noise level predicted from Fig 1 should be reduced by 1 dB(A).

Small additions to Fig 1 values are also warranted for road gradients; thus alongside moderate gradients (more than 1 in 50, but not greater than 1 in 25) 1 dB(A) should be added and for steeper gradients (up to 1 in 12) the addition should be 2 dB(A).

Ground absorption

A ground surface that is acoustically soft, eg grassland as opposed to paved areas, reduces sound propagation over it in a complex manner. For propagation distances greater than about 20 m, this effect can reduce the noise exposure level. The effect is mainly significant for low propagation heights above such ground surfaces and, as a rough guide, the following table indicates the extra attenuation that might be expected due to propagation at various heights over absorbing ground, assuming the source to be 0·7 m above the level of the motorway.

Mean height of propagation path (metres)	Ground attenuation dB(A)
6	1
4·5	2
3	3
1·5	4
0·7	5

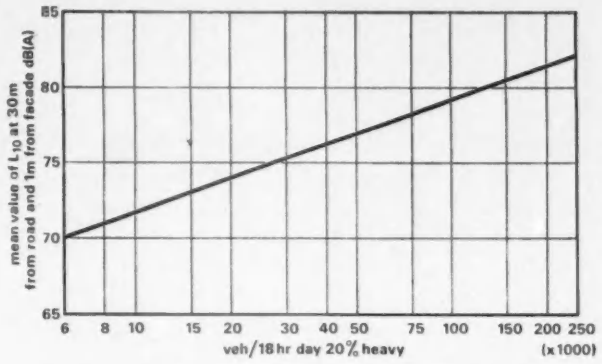

mean value of L_{10} at 30m from road and 1m from facade dB(A)
85
80
75
70
65
6 8 10 15 20 30 40 50 75 100 150 200 250
veh/18 hr day 20% heavy
(x1000)

Fig 1 Basic chart for prediction of noise exposure: L_{10} levels at 30 m from road and 1 m from façade; mean traffic speed 75 km/h

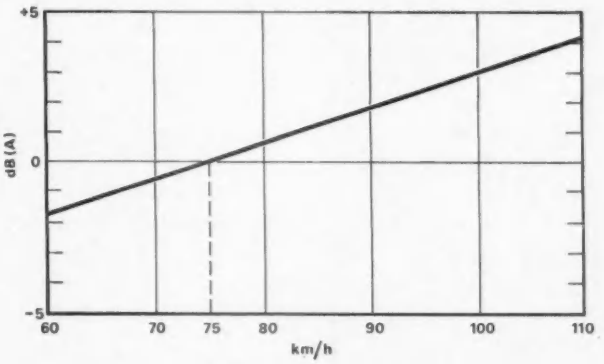


Fig 2 Correction for mean traffic speed

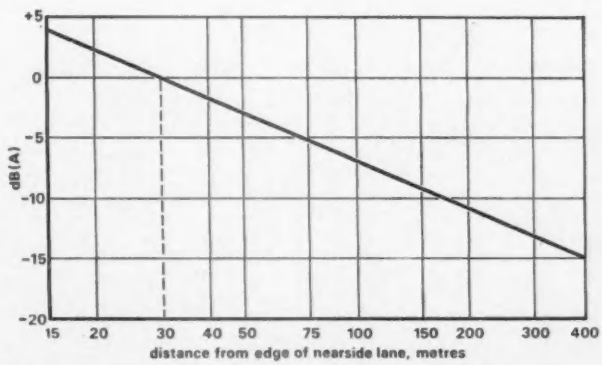


Fig 3 Correction for distance

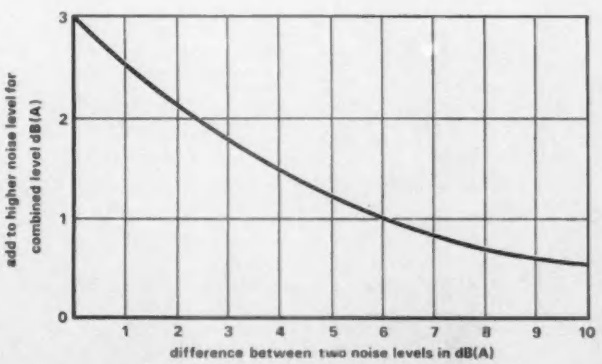


Fig 4 Combination of exposures from two roads

Corrections on this basis can be made to calculated exposure levels, but no allowance should be made if a fair proportion of the ground area is paved, or if there is to be screening by buildings or barriers, because the latter will eliminate close-to-ground propagation. Screening roads by constructing them in cuts is a special case which has not been fully investigated, but until more is known it is suggested that ground attenuation should be discounted as with other forms of barrier, only the screening effect being allowed for.

Noise screens

Well-designed noise screens can sometimes achieve as much as 20 dB(A) reduction, although 10 dB(A) would be more typical. The screen should provide as great an angle of acoustic shadow as possible. Accordingly it is an advantage to put it close to the noise source (or to the receiver in some cases), to make it as high as practicable and of adequate length. For acoustic reasons the screen should be imperforate, but not necessarily of massive construction. As the attenuation due to the screen is virtually limited by diffraction to 20 dB(A), an average sound reduction of 25–30 dB through the screen itself would be ample, and this can be obtained by a solid panel mass of about 20 kg/m^2; in most cases a mass of only 10 kg/m^2, giving an average sound reduction of nearly 25 dB, would be sufficient; screens designed to give no more than 10 dB attenuation do not need a mass of more than 5 kg/m^2. The mass requirement applies to single-leaf construction or, in the case of multi-leaf screens, to at least one leaf.

For design purposes, a useful way of presenting the attenuation performance of noise screens is graphically, based on the difference between the shortest air paths from source to reception point with and without the screen, assuming the source to be a point 0·7 m above the ground at the centre of the motorway.

Given this information, the attenuation due to the presence of the screen can be read from Fig 5, which shows the extra attenuation of L_{10} provided by the noise screen over the calculated L_{10} without the screen and with no allowance for ground absorption. If L_{10} has been obtained by measurement under conditions where ground absorption is known to be present, an addition should be made to compensate for this absorption before calculating new levels due to the noise screen. An important condition applying to Fig 5 is that the screen should be a very long one, so that the performance is not affected by traffic noise outflanking the screen round the ends. Because motorway noise is a very extended source, short screens are not normally of much use, as will appear later.

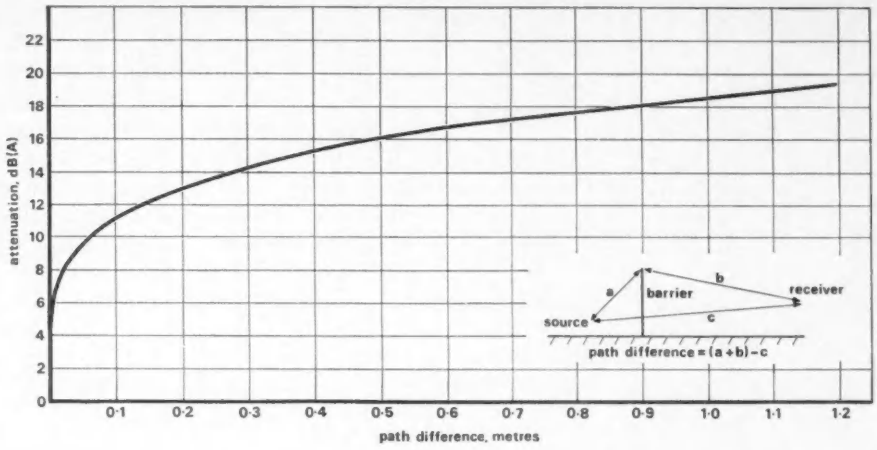


Fig 5 Reduction of L_{10} by very long barriers

Fig 6 is supplementary to Fig 5 and provides a design aid in the form of a nomogram for obtaining noise attenuations due to barriers, avoiding the need to calculate path differences. The data required for using the nomogram are obtained by setting up a scale cross-section showing the relative positions of source, receiver and barrier. Again the source is assumed to be a point 0·7 m above the ground surface at the middle of the motorway, which for a dual carriageway is the middle of the central reservation. This source point should be joined to the reception point (1 m from a façade) by a straight line—the sight-line. Scale the length of this sight-line, the relative position along it of the barrier, and the perpendicular height above it of the top of the barrier, the latter dimension being the effective barrier height.

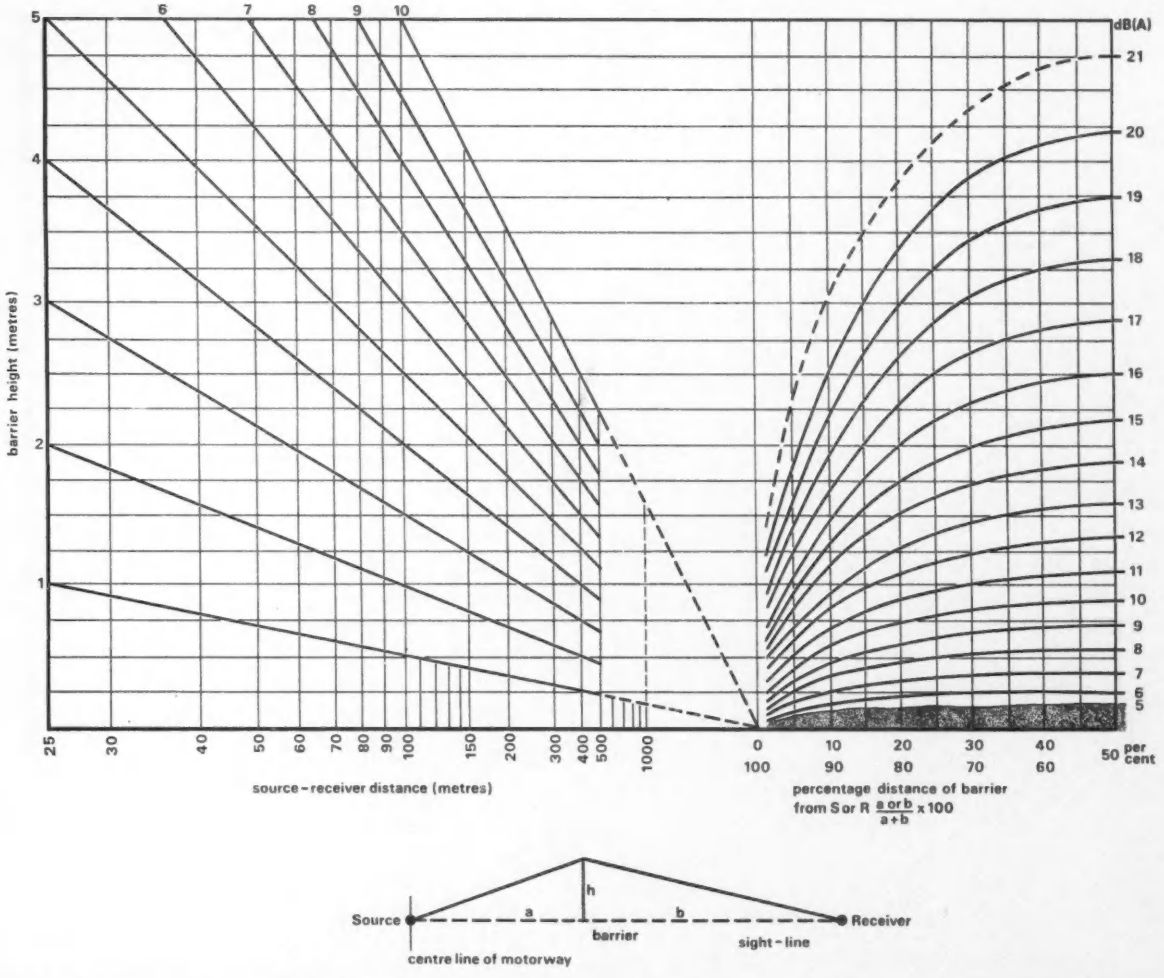


Fig 6 Nomogram for attenuation of traffic noise L_{10}, by long barriers

From this information, Fig 6 may be used to find the barrier attenuation. First select the position along the horizontal scale marked 25–500 (1000) metres (on the left of the diagram) corresponding to the source-to-receiver distance—say 100 m, as an illustration; at this position, using the variable scale indicated by the diverging lines radiating from 0, set up vertically the effective barrier height—say 1·5 m. From this point on the height scale follow the horizontal line into the right-hand side of the diagram until it reaches that point vertically above the base scale 0–100 per cent which represents the relative position of the barrier between source and receiver—say 25 per cent. At this point of intersection the nearest attenuation contour gives the attenuation in dB(A) due to the barrier, provided of course that the barrier is extensive in both directions. The values quoted above by way of example will be seen to give an attenuation of 10 dB(A).

Attention is drawn to the fact that Fig 6 is based on sight-line distances and perpendicular heights of barriers above the sight line. If the distance is measured from the plan rather than from the section, and especially if the vertical height of the barrier above the sight-line is used instead of the perpendicular height, a small error can arise in some cases. The error is negligible unless the sight line is quite steep; for example, a sight-line slope of 30° may give an error of about 1 dB(A). Such errors are more likely to occur with short distances and high barriers. Working to sight-line distances and perpendicular barrier heights eliminates error and is generally advisable if the sight-line slope is steeper than about 15°.

As already stated the calculation from Figs 5 or 6 assumes the noise screen to be a very long one, so that it is not outflanked by noise from more distant traffic. In fact, some restriction on the effectiveness of noise screens will occur unless the distance from the reception point to the end of the screen is at least ten times the shortest path to the screen. Thus, for a point 30 m from the screen the length of the screen needs to extend at least 300 m in each direction or a minimum of 600 m in total length; if the screen is shorter, the attenuation will be less than the full potential of a long screen of the same design. If the reception point is equidistant from the ends of the screen, an indication of the restricted performance can be obtained from Fig 7, which is based on the angle subtended to either end, the potential reduction of a similar but much longer noise barrier having first been found from Figs 5 or 6. When the reception point is not equidistant from the ends of the screen, a further step is necessary, using Fig 8. The reduction is first calculated for a long screen from Figs 5 or 6, and the result is modified separately for each of the angles subtended to either end, using Fig 7 as before; the difference between the two new results is then used in Fig 8 to find the amount that should be added to the lower of the two separate results in order to arrive at the net reduction.

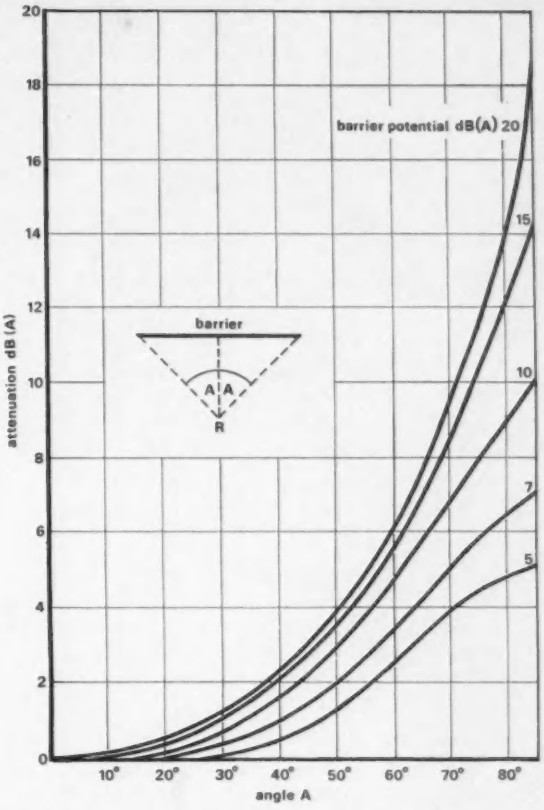
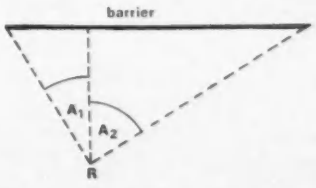


Fig 7 Performance of partial screens, L_{10}



I_1 = attenuation at R due to A_1 } from Fig 7
I_2 = " " " " A_2 }
C = correction, from curve below
Overall attenuation at R = (lower of I_1 or I_2) + C

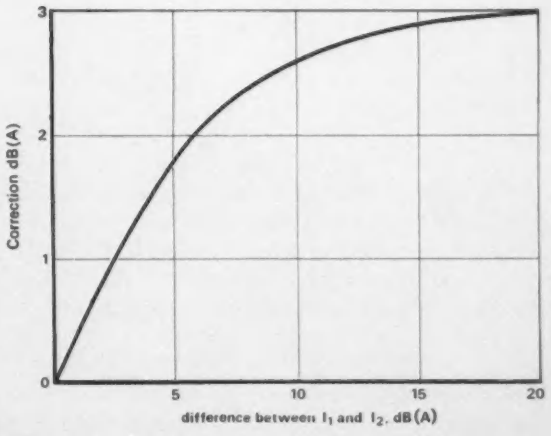


Fig 8 Calculation of reduction due to non-symmetrical partial screening

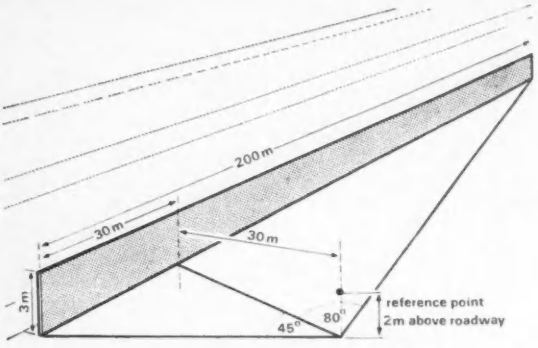


Fig 9 Example of non-symmetrical partial screen

As an example of a non-symmetrical partial screen (see Fig 9), a 3 m high screen 200 m long and 15 m from the middle of the motorway will be assumed, with the reception point 2 m above road level at 30 m from the screen opposite a point 30 m from one end of it, thus subtending angles to the ends of the screen of 45° and 80°. From Fig 6 we find that if the noise screen had been very long in both directions it would have given a reduction of 12 dB(A) at the reception point. This is the screen potential to be used in Fig 7. Reading from Fig 7 the attenuations associated with angles of 45° and 80° at the potential of 12 dB(A), we get values of 2·5 and 10 dB(A) respectively, a difference of 7·5 dB(A). From Fig 8 the difference 7·5 dB(A) gives C = 2 dB(A), and the net reduction is (2·5 + 2) dB(A) = 4·5 dB(A), say 5 dB(A), which is considerably less than the 12 dB(A) reduction of a long screen of the same design.

Buildings may themselves be used as noise screens and their effectiveness in screening other buildings can be calculated in the manner already described, though complex groups of buildings may affect the levels of inter-reflections between façades. L_{10} values at façades facing away from the road can be expected to be on average 15 dB(A) lower than on the exposed side.

Contrary to widespread belief, tree belts are not much use as noise screens unless they are very wide and dense. A width of at least 50 m is necessary to give a reduction of about 10 dB(A) and a high proportion of the trees and shrubs must be evergreen if the protection is to be maintained throughout the year. If a belt of trees exists, it may of course be possible to make use of such protection as it can offer; but because of the time taken for new planting to mature it is seldom realistic to regard new tree belts as a solution to the noise problem of motorways near to housing. Any benefit of this nature from trees should usually be regarded as fortuitous rather than a planned contribution to the protection required. In some cases trees give a substantial benefit by obscuring the view of the traffic, which seems to render the noise less objectionable even though it is not actually abated by the trees.

Measuring L_{10}

To measure L_{10} accurately involves a statistical analysis of the fluctuating traffic noise levels and requires elaborate equipment. With the microphone one metre from the external façade of a dwelling the noise levels are recorded continuously for a period of several minutes at precisely one-hour intervals throughout the 18-hour period from 6 am to midnight of a typical weekday, preferably Tuesday to Thursday. The hourly sampling period should be long enough to include the passage of at least 50 vehicles and preferably 100 or more. On busy traffic routes of 3000 or more vehicles per hour, this means recording for about two minutes in every hour; longer sampling periods are needed for roads with sparse traffic. A period should be chosen when the wind is adverse (from road to microphone) and the average wind component about 10 km/h. Having derived individual L_{10} values from the results for each hourly period, the arithmetic mean of the 18 values is found. The result may be designated $L_{10}(18h)$ to distinguish it from the L_{10} values for hourly samples, but the term L_{10} in general use signifies L_{10} (18h) unless otherwise stated. The procedure described will give an accurate measure of L_{10} under the conditions prevailing at the time of the measurements.

Traffic conditions do not vary greatly from one weekday to another, especially within the midweek period Tuesday to Thursday, but weather conditions have no such regular pattern and the weather (particularly wind direction) can influence noise propagation markedly. Therefore weather conditions should be observed and recorded at the time of measurement. Noise control decisions may sometimes be based on typical wind conditions at the particular site, but an adverse wind component of 10 km/h is the basis of all estimates of noise level in this digest.

It may not always be practicable to adopt this prolonged method of measurement, whilst nevertheless measurements at a particular site may be desired in addition to any predictions. In these circumstances, a simpler measuring procedure using a sound level meter may be found useful. Basically, the procedure consists of noting sound level meter readings in rapid but regular succession over a reasonable short-term period, and converting the results to L_{10} either by a simple statistical analysis or, more simply, by crossing out the top 10 per cent of the readings and taking the highest remaining level. Readings can be facilitated by a simple attachment to the sound level meter to cue the readings by a light-flash at regular intervals. Some recent trials[4] indicate that by this means readings of motorway noise at four-second intervals over a period of 15 minutes give short-term values of L_{10} that are accurate within about 1 dB(A) of the results obtained by more complex methods. Moreover, on roads with heavy traffic flows, the approximate $L_{10}(18h)$ level can be obtained by measuring the short-term value of L_{10} during the middle of the day

(but avoiding peak traffic periods) and subtracting 2 dB(A). In all cases, however, the results obtained will be for the wind and weather conditions at the time of testing. It may be as well, too, to repeat that for design purposes L_{10} is required at positions 1 m from the façades of buildings. If possible, therefore, any measurements, whether short-term values or not, should be made 1 m from a façade; otherwise (if well clear of any reflecting wall) 3dB(A) should be added to the measured result before applying any recognised external standard.

Sound insulation

Every building gives to its occupants some measure of protection from external noise. The noise level inside an 'uninsulated' dwelling, away from the windows, should be at least 10 dB(A) less than the outside level, this being the minimum insulation expected even with partly open windows. If the external level of 70 dB(A) cannot be met, it may still be possible to restore a satisfactory acoustic environment indoors by improving the sound insulation of the structure, though this is not a complete solution because a satisfactory acoustic environment outdoors is also important. Moreover, the individual sound insulation of dwellings imposes certain restraints. The basis of noise protection by the building façade is to keep the windows shut, and sometimes, if the noise exposure demands it, to provide double windows. Keeping windows closed raises a problem of ventilation. If mechanical ventilation is introduced, it may be necessary to attenuate noise entering at the ventilation inlets or outlets and to suppress any noise created by the fans and motors, a problem that has already been discussed in Digests 128 and 129.

Limits of application

In this digest a method has been proposed for estimating L_{10} due to free-flowing traffic for a range of circumstances. Until more knowledge has revealed any significant differences it is suggested that the same procedures may be useful for other free-flowing traffic. The rules do not, however, apply to ordinary urban roads with interrupted traffic flows, a problem which calls for further study. Again, the digest is primarily concerned with traffic noise as it affects dwellings; while it is true that the method of estimating L_{10} is independent of the type of building being considered, the application to buildings other than dwellings requires the establishment of standards for these buildings in terms of L_{10}.

References

1 Designing against noise from road traffic; W E Scholes and J W Sargent: BRS Current Paper 20/71
2 Government Committee on the Problem of Noise, Final Report; Command Paper 2056, HMSO 1963
3 DOE, Report of Urban Motorways Committee; New Roads in Towns: HMSO July 1972
4 Statistical Analysis from a Sound Level Meter; W E Scholes and A C Salvidge; BRS EN 49/72

Let us help you

The Building Research Advisory Service can help you solve construction problems. Problems of every sort. From the simple ones which require only a piece of literature or an off-the-cuff answer at no charge, to more complex problems requiring investigation on site or laboratory study for which we charge on a time basis.
Anyone can use this service. There are five centres: Watford, Birmingham and Glasgow tackle most subjects, fire enquiries are dealt with at Borehamwood and timber problems are answered by Princes Risborough.

If you become an Associate Member (fee: £5 a year) you get a credit service with 10% discount, priority over non-associates and free Building Research Digests (including revisions). Contact any of the Advisory Centres below and we will send you more details about the Service and Associate membership.

Advisory centres at:

Building Research Advisory Service
Building Research Station
Garston, Watford WD2 7JR
Telephone Garston (Herts) 76612
Telex 923220

Building Research Advisory Service
Birmingham Engineering and Building Centre
Broad Street, Birmingham B1 2DB
Telephone 021-643 8961

Building Research Advisory Service
Fire Research Station, Borehamwood,
Hertfordshire, WD6 2BL
Telephone 01-953 6177

Building Research Advisory Service
Princes Risborough Laboratory
Princes Risborough
Aylesbury, Buckinghamshire
Telephone Princes Risborough 3101

Building Research Advisory Service
Scottish Laboratory, Kelvin Road,
East Kilbride, Glasgow G75 0RZ
Telephone East Kilbride 33941

Department of the Environment **Building Research Establishment**

Prepared at Building Research Station, Garston, Watford WD2 7JR
© 1973
Technical enquiries arising from this Digest should be directed to Building Research Advisory Service at the above address.
Published by Her Majesty's Stationery Office and printed in England by Benham and Company Limited, Colchester.
Single copies 5p each. Annual subscription inclusive of postage £1·20 for 18 issues.
Quantity rates (excluding postage) for bulk supply of any one Digest: 25 for £1·05, 50 for £1·65, 100 for £3.

Dmd. 505866 K704 SBN 11 721596 1